

3. ANALYSIS BY FOCUS AREA

The FY 2004 SDA logging program was part of an overall plan to evaluate long-term health and safety risks associated with waste buried in the SDA. The logging program was subdivided into focus areas selected to address a specific data need.

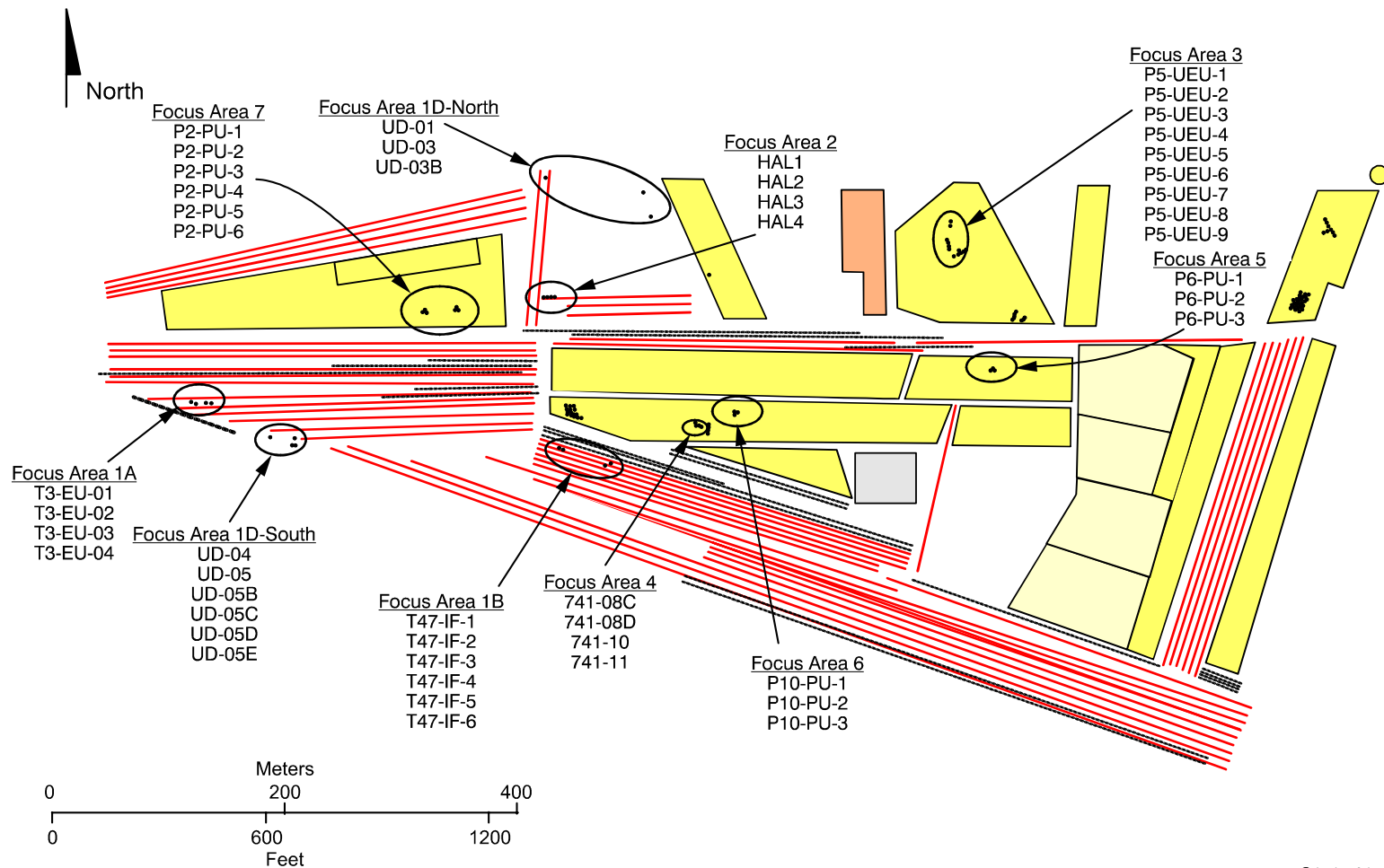
3.1 Overview of FY 2004 Focus Areas

Figure 3-1 shows the location of the FY 2004 logging probes, subdivided by focus area. Table 3-1 presents the nomenclature used in this report to identify each focus area along with brief descriptions of each focus area, location information, and a list of the probes installed. Probe locations for each focus area were selected after combined analysis of inventory records and surface geophysics data. Each installed probe was first logged using the neutron-neutron moisture tool. Moisture data then were analyzed to determine thickness of the soil overburden at each probe location. The passive spectral gamma ray, neutron-activated spectral gamma ray, and passive-neutron tools were then deployed from near the base of the overburden down to the bottom of the probe. Several probes were selected for deployment of the azimuthal spectral gamma ray tool in cases where these data were considered useful for meeting focus area objectives.

Table 3-1. Descriptive summary of focus areas investigated during the FY 2004 logging program.

| Focus Area | Waste Type Investigated | Pit or Trench Location | Probes Installed |
|------------|--|------------------------|--|
| 1A | Enriched uranium-bearing waste from RFP Building 881 | Trench 3 | T3-EU-01, T3EU-02, T3-EU-03, T3-EU-04 |
| 1B | Eight NRF shipments of waste similar to spent nuclear fuel | Trench 47 | T47-IF-1, T47-IF-2, T47-IF-3, T47-IF-4, T47-IF-5, T47-IF-6 |
| 1D North | Various undocumented waste disposals | North SDA | UD-01, UD-03, UD-03B |
| 1D South | Various undocumented waste disposals | South SDA | UD-04, UD-05, UD-05B, UD-05C, UD-05-D, UD-05-E |
| 2 | Liquid radioactive waste associated with a diatomaceous absorbent material | Trench 24 | HAL1, HAL2, HAL3, HAL4 |
| 3 | Uranium- and plutonium-contaminated RFP sludge and graphite waste | Pit 5 | P5-UEU-1, P5-UEU-2, P5-UEU-3, P5-UEU-4, P5-UEU-5, P5-UEU-6, P5-UEU-7, P5-UEU-8, P5-UEU-9 |
| 4 | Follow-up investigation of suspected RFP Series 741 sludge disposal | Pit 10 | 741-08C, 741-08D, 741-10, 741-11 |
| 5 | Suspected plutonium waste area | Pit 6 | P6-PU-1, P6-PU-2, P6-PU-3 |
| 6 | Suspected plutonium waste area | Pit 10 | P10-PU-1, P10-PU-2, P10-PU-3 |
| 7 | Suspected concentrated plutonium waste area | Pit 2 | P2-PU-1, P2-PU-2, P2-PU-3, P2-PU-4, P2-PU-5, P2-PU-6 |

NRF = Naval Reactors Facility
RFP = Rocky Flats Plant
SDA = Subsurface Disposal Area



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Figure 3-1. Location of the FY 2004 Subsurface Disposal Area logging probes, divided into focus areas.

3.2 Focus Area 1A: Building 881 Waste

Four probes were installed in Focus Area 1A to explore for enriched uranium waste that could be a source of contaminated vadose zone pore water. Figure 3-2 shows the interpreted location of a Rocky Flats Plant (RFP) waste shipment (RFODOWSR102/10/55800) that included 16 55-gal drums and one 30-gal drum of Building 881 solid waste. Building 881 waste is suspected of containing material contaminated with enriched uranium. The four probes installed in the vicinity of this shipment, T3-EU-01 through T3-EU-04, are also shown.

Tables 3-2 and 3-3 present summaries of the logged intervals and detected contaminants for each of the Focus Area 1A probes. A logging data summary chart for each Focus Area 1A probe is included in Appendix B. Note that radionuclide levels are presented in units of activity concentration. These values should be understood as *apparent* concentrations, because the actual concentration is highly dependent on heterogeneity in the vicinity of the probehole.

Table 3-2. Logging completion summary showing depth intervals logged for each Focus Area 1A probe.

| Well ID | Passive Neutron | | Passive Gamma | | N-gamma | | Moisture | |
|----------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) |
| T3-EU-01 | 2.25 | 17.57 | 2.00 | 17.97 | 2.00 | 16.92 | 0.25 | 18.06 |
| T3-EU-02 | 2.25 | 20.94 | 2.00 | 21.41 | 2.00 | 20.33 | 0.25 | 21.41 |
| T3-EU-03 | 2.25 | 10.96 | 2.00 | 11.41 | 2.00 | 10.32 | 0.25 | 11.48 |
| T3-EU-04 | 2.25 | 12.58 | 2.00 | 12.17 | 2.00 | 11.94 | 0.25 | 13.09 |

Table 3-3. Radionuclide detection summary for Focus Area 1A.^a

| Well ID | Cs-137 662 keV (pCi/g) | Co-60 1,332 keV (pCi/g) | Pu-239 375 keV (pCi/g) | Am-2416 62 keV (pCi/g) | Np-237 312 keV (pCi/g) | U-235 186 keV (pCi/g) | U-238 1,001 keV (pCi/g) | Chlorine 1,151 keV (counts/ second) |
|------------------|------------------------------|-------------------------------|------------------------------|------------------------------|------------------------------|-----------------------------|-------------------------------|--|
| T3-EU-01 | 3.2 | 5.0 | ND | ND | ND | ND | ND | 2.9 |
| T3-EU-02 | 5,504.8 | 1.0 | ND | ND | ND | 26.5 | 1,235.7 | 8.0 |
| T3-EU-03 | 31.7 | ND | ND | ND | ND | 3.4 | 178.8 | 2.0 |
| T3-EU-04 | 0.3 | ND | ND | ND | ND | ND | 22.9 | 1.2 |
| MAX ^b | 140.5 | 814.2 | 194,171,000 | 30,449,000 | 4,881 | 344.9 | 220,894 | 38 |
| PROBE | 741-04 | P9-FI-05 | P9-20 | 743-08-02 | DU-08 | 743-08 | 743-08 | P9-03 |

a. Concentration estimates obtained from geophysical logging measurements can be significantly affected by heterogeneous subsurface conditions; values presented in this table should be viewed as *apparent* concentration.

b. Maximum observed value of radionuclide or element from all previous SDA logging.

NA = not applicable

ND = not detected

Table 3-3 shows that both cesium–cobalt and U-235:U-238 radionuclide associations are present. The highest observed Cs-137 apparent concentration is 5,504.8 pCi/g, which exceeds the previous highest Cs-137 level logged anywhere at the SDA.

The uranium observed in probes T3-EU-02 and T3-EU-03 was evaluated to assess the evidence for enriched uranium waste. Table 3-4 gives the U-235:U-238 activity ratios and mass ratios at each point where both U-235 and U-238 were detected. These ratios have not been corrected for differential gamma ray attenuation, but are suggestive of depleted uranium. The chlorine collocated with uranium in these probes may reflect PERC sill bottoms.

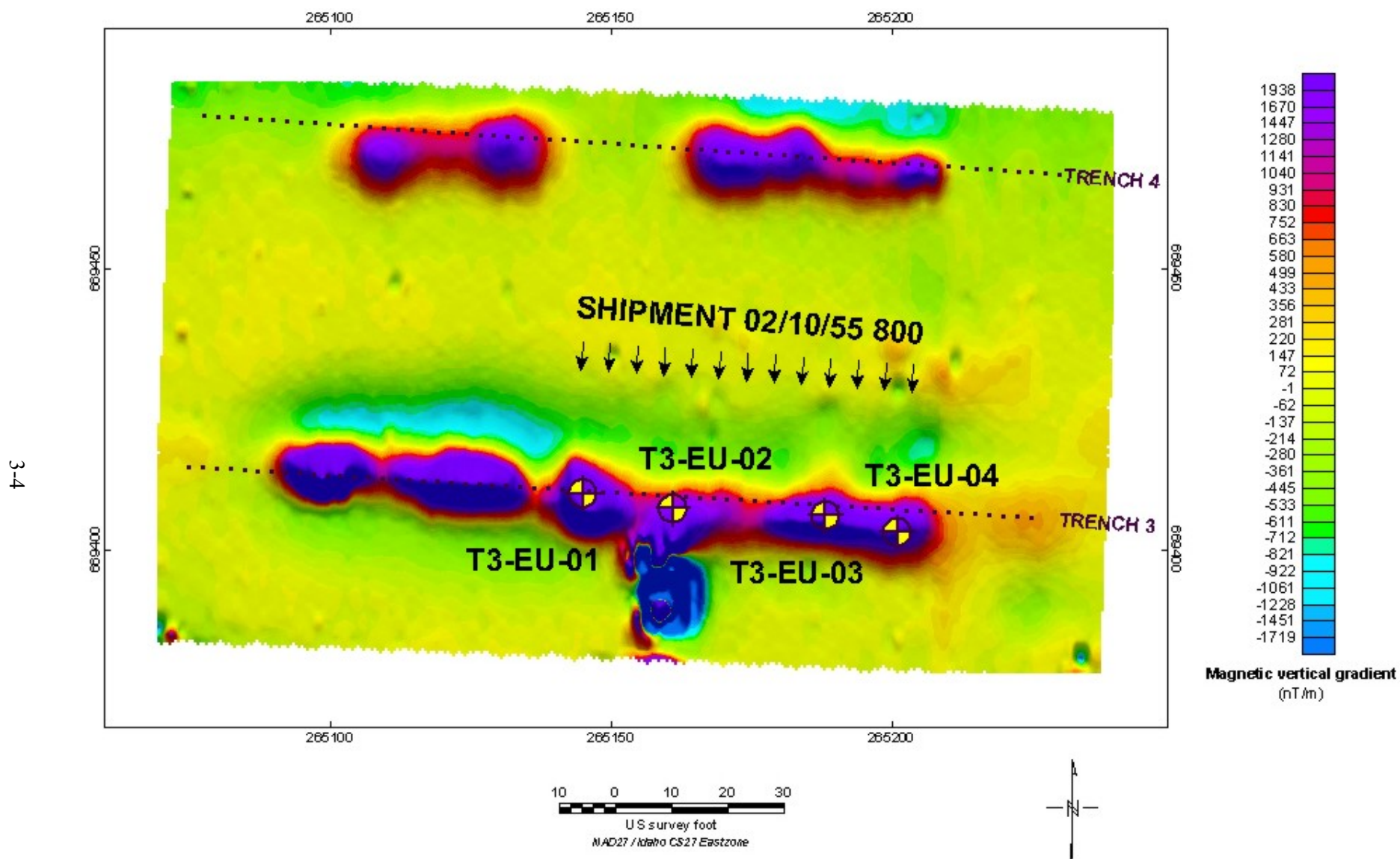


Figure 3-2. Map showing the location of Focus Area 1 probes and Rocky Flats Plant shipment RFODOWSR102/10/55800 in Trench 3.

Table 3-4. Summary of uranium detection and ratios in Focus Area 1A.^a

| Well_ID | Depth (ft) | U-235 ^b 186-keV (pCi/g) | U-238 1,001-keV (pCi/g) | Activity Ratio ^c U-235:U-238 | Mass Ratio ^c U-235:U-238 |
|----------|---------------|--|-------------------------------|--|--|
| T3-EU-02 | 9.50 | 17.4 | 982.1 | 0.0177 | 0.0028 |
| T3-EU-02 | 8.89 | 19.3 | 1,130.8 | 0.0171 | 0.0027 |
| T3-EU-02 | 8.50 | 26.5 | 1,235.7 | 0.0215 | 0.0033 |
| T3-EU-02 | 8.00 | 19.8 | 1,060.1 | 0.0187 | 0.0029 |
| T3-EU-02 | 7.50 | 12.7 | 681.8 | 0.0187 | 0.0029 |
| T3-EU-02 | 7.00 | 4.0 | 275.4 | 0.0147 | 0.0023 |
| T3-EU-03 | 5.00 | 3.4 | 1,78.8 | 0.0190 | 0.0029 |

a. Concentration estimates obtained from geophysical logging measurements can be significantly affected by heterogeneous subsurface conditions; values presented in this table should be viewed as *apparent* concentration.

b. U-235 apparent concentrations not corrected for potential Ra-226 interference.

c. Activity ratios are derived from constants obtained from GE (1989): (1) typical activity ratios: <0.04507 (depleted), 0.04507 (natural), >0.04507 (enriched); (2) typical mass ratios: <0.00696 (depleted), 0.00696 (natural), >0.00696 (enriched).

Azimuthal logging was performed at 8.0 ft in probeholes T3-EU-02 and T3-EU-03. Azimuthal data are presented in Section 4.5.

3.3 Focus Area 1B: Naval Reactors Facility Reactor Core Components

Target shipments for Focus Area 1B are reactor core and loop components generated at the Naval Reactors Facility (NRF) and buried in Trench 47. Figure 3-3 shows the location of the targeted shipments. Locations of the new probes, T47-IF-1 through T47-IF-6, are also shown. Probes T47-IF-1 through T47-IF-4 were placed adjacent to geophysical anomalies that were indicative of massive metal objects. Probes T47-IF-5 and T46-IF-6 were installed directly adjacent to probes T47-IF-2 and T47-IF-1 to facilitate detailed investigation of radionuclide zones observed in logging results from the first four probes. All six probes met refusal from 9–12 ft below ground surface (bgs).

Tables 3-5 and 3-6 present summaries of the logged intervals and the detected contaminants for each of the Focus Area 1B probes. A logging-data-summary chart for each Focus Area 1B probe is included in Appendix B. Note that radionuclide levels are presented in units of activity concentration. These values should be understood as *apparent* concentrations, because the actual concentration is highly dependent on heterogeneity in the vicinity of the probehole.

Table 3-6 shows that the cesium-cobalt radionuclide group is observed in all six probeholes. The maximum measured levels are 17,184 pCi/g of Cs-137 and 24 pCi/g of Co-60. A small Am-241 peak correlates with the cesium-cobalt peak in Probehole T47-IF-1. Weak, single-point U-235 and U-238 anomalies occur in Probehole T47-IF-5. Low-level chlorine counts were observed in all probes except Probehole T47-IF-3.

In probes T47-IF-2, T47-IF-3, and T47-IF-5, the cesium-cobalt levels reach a maximum value at the deepest measurement point, suggesting that the radionuclide zone continues below the probe bottom. This may reflect contamination that has migrated into basalt or other type of hard layer beneath the waste zone, or it may mean that the probe struck impenetrable waste at the refusal depth. In either case, it is impossible to determine the peak radionuclide level for these zones.

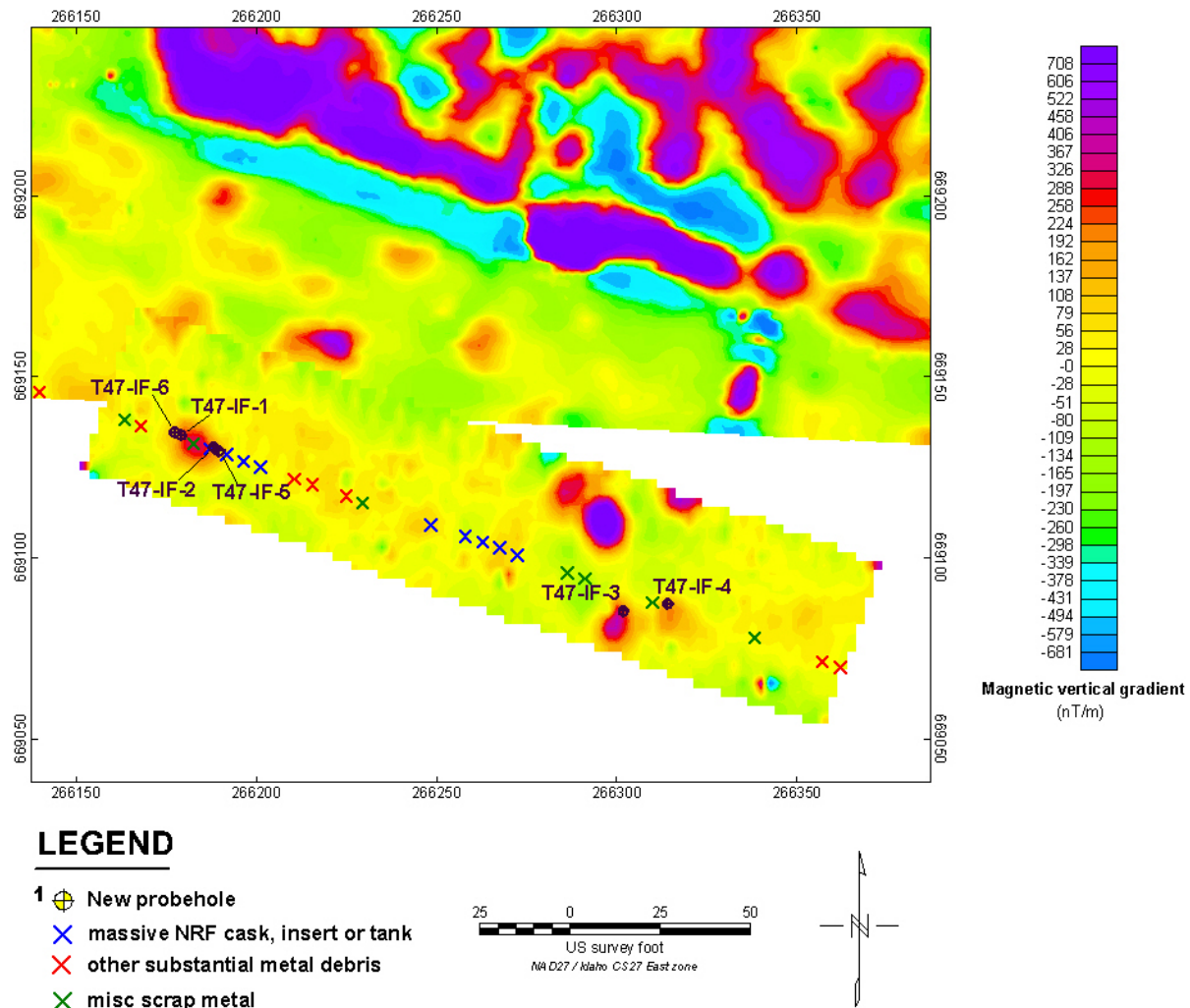


Figure 3-3. Map showing the location of targeted shipments of Naval Reactors Facility core components in Focus Area 1B.

Table 3-5. Logging completion summary showing depth intervals logged for each Focus Area 1B probe.

| Well_ID | Passive Neutron | | Passive Gamma | | N-gamma | | Moisture | |
|----------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) |
| T47-IF-1 | 2.25 | 10.67 | 2.00 | 11.05 | 2.00 | 9.97 | 0.25 | 11.13 |
| T47-IF-2 | 2.25 | 9.92 | 2.00 | 10.29 | 2.00 | 9.26 | 0.24 | 10.37 |
| T47-IF-3 | 2.25 | 10.66 | 2.00 | 11.03 | 2.00 | 10.00 | 0.24 | 11.10 |
| T47-IF-4 | 2.25 | 8.78 | 2.00 | 9.19 | 2.00 | 8.15 | 0.24 | 9.26 |
| T47-IF-5 | 2.25 | 10.14 | 2.00 | 10.61 | 2.00 | 9.53 | 0.25 | 10.64 |
| T47-IF-6 | 2.25 | 10.71 | 2.00 | 11.12 | 2.00 | 10.04 | 0.25 | 11.17 |

Table 3-6. Radionuclide detection summary for Focus Area 1B.^a

| WELL ID | Cs-137 662 keV (pCi/g) | Co-60 1,332 keV (pCi/g) | Pu-239 375 keV (pCi/g) | Am-241 662 keV (pCi/g) | Np-237 312 keV (pCi/g) | U-235 186 keV (pCi/g) | U-238 1,001 keV (pCi/g) | Chlorine 1,151 keV (counts/ second) |
|------------------|------------------------------|-------------------------------|------------------------------|------------------------------|------------------------------|-----------------------------|-------------------------------|--|
| T47-IF-1 | 1,942.9 | 3.4 | ND | ND | ND | ND | ND | 1.1 |
| T47-IF-2 | 2,295.5 | 13.2 | ND | ND | ND | ND | ND | 1.2 |
| T47-IF-3 | 3.2 | 24.6 | ND | ND | ND | ND | ND | 0.1 |
| T47-IF-4 | 8.9 | 0.2 | ND | ND | ND | ND | ND | 1.4 |
| T47-IF-5 | 17,184.2 | 1.2 | ND | ND | ND | ND | ND | 2.0 |
| T47-IF-6 | 2,275.4 | 0.8 | ND | ND | ND | 24.3 | 21.0 | 1.8 |
| MAX ^b | 140.5 | 814.2 | 194,171,000 | 30,449,000 | 4,881 | 344.9 | 220,894 | 38 |
| PROBE | 741-04 | P9-FI-05 | P9-20 | 743-08-02 | DU-08 | 743-08 | 743-08 | P9-03 |

a. Concentration estimates obtained from geophysical logging measurements can be significantly affected by heterogeneous subsurface conditions; values presented in this table should be viewed as *apparent* concentration.

b. Maximum observed value of radionuclide or element from all previous SDA logging.

NA = not applicable

ND = not detected

SDA = Subsurface Disposal Area

The cesium-cobalt peaks at 8 ft in Probehole T47-IF-1 and 7.5 ft in Probehole T47-IF-2 could correspond to a single radionuclide zone that lies between these two probes and corresponds exactly with a geophysical anomaly. The association between Cs-137 (a fission product) and Co-60 (an activation product) suggests fuel-related materials, though fuel specimens are unlikely, considering the lack of uranium peaks. It is worth noting that the cesium and cobalt peaks are well correlated (i.e., they increase and decrease in tandem). This pattern suggests that the radiation sources are cesium-contaminated metal objects rather than separate distributions of activated metals and fission products. In the latter case, cesium and cobalt peaks would not be expected to have such a high degree of correlation.

Figure 3-4 shows a comparison between probeholes T47-IF-1 and T47-IF-6. The thickness, magnitude, and depth of the cesium-cobalt radionuclide zone in Probehole T47-IF-6 are similar to counterparts observed in Probehole T47-IF-1, suggesting that both probes intersect a common radionuclide zone. Figure 3-5 shows a comparison between probeholes T47-IF-2 and T47-IF-5. Probeholes T47-IF-2 and T47-IF-5 show increasing cesium-cobalt levels at the deepest measurement point, suggesting that the radionuclide zone continues within the soil layer (or waste) beneath the probe. The apparent Cs-137 concentration of 17,184 pCi/g observed at the bottom of Probehole T47-IF-5 is the highest Cs-137 level observed anywhere during SDA Type A probehole logging.

Careful examination of Figure 3-3 shows that Probe T47-IF-5 is closer to the historic position of several NRF casks than is Probe T47-IF-2. One possible interpretation of the evidence is that the targeted geophysical anomaly is not associated with the NRF cask shipments, and that the historical records give an accurate depiction of the true shipment locations. In this case, the increased Cs-137 levels in Probe T47-IF-5 are interpreted as an indication that this probe is very close to an NRF shipment.

Azimuthal logging was performed at 8.0 and 10.0 ft in probeholes T47-IF-1 and T47-IF-2. Azimuthal data are presented in Section 4.5.

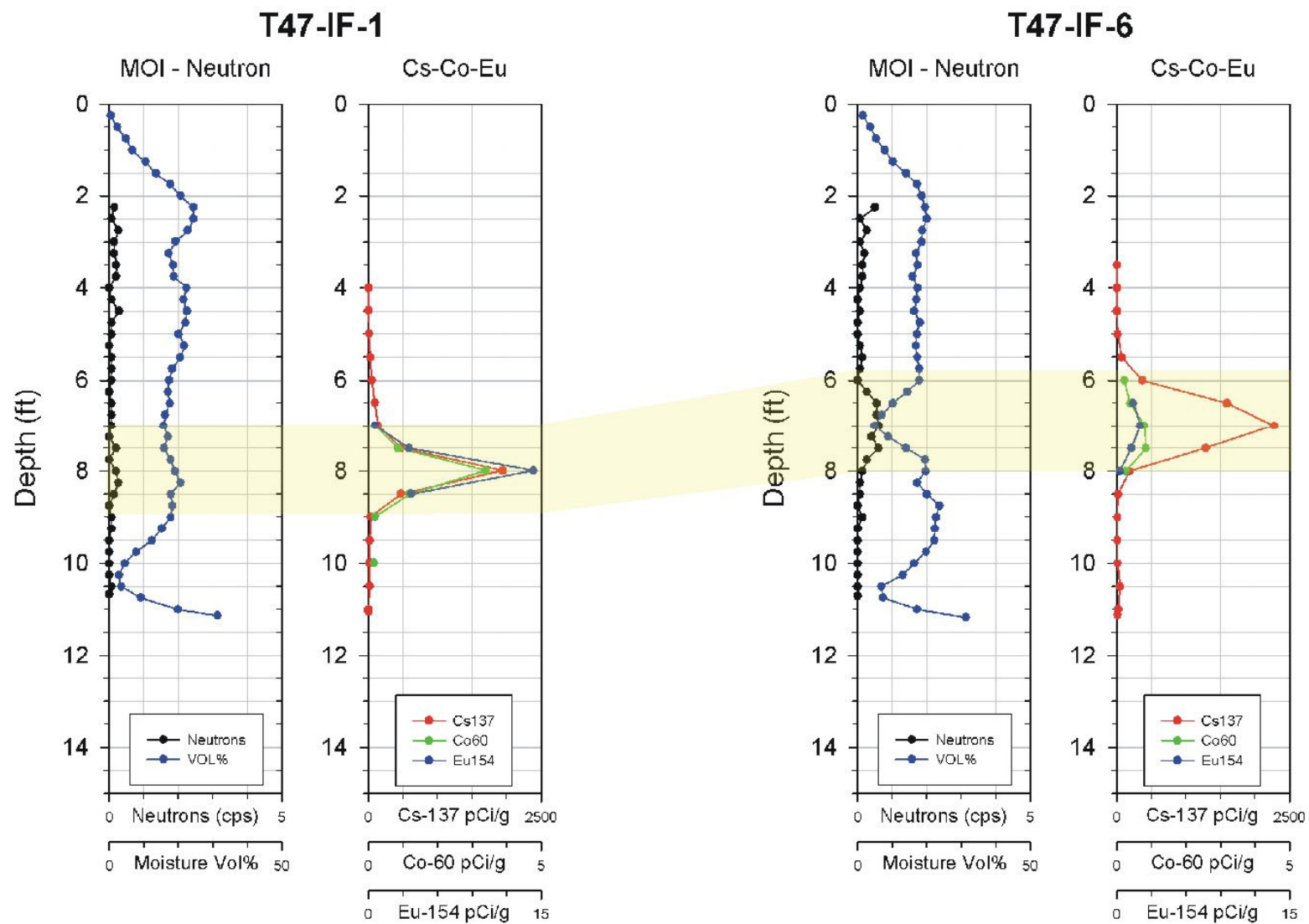


Figure 3-4. Comparison of selected logging results for probes T47-IF-1 and T47-IF-6.

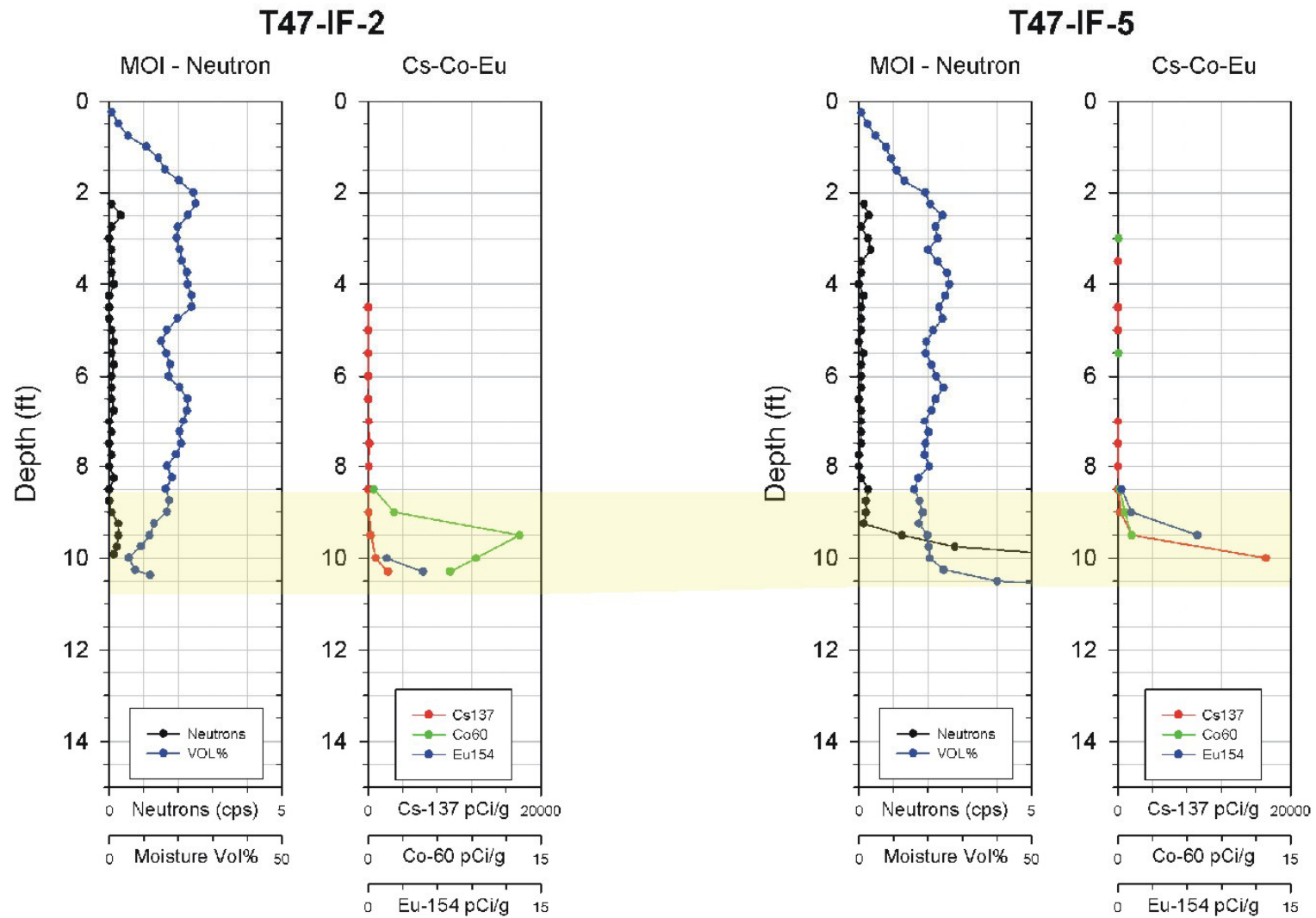


Figure 3-5. Comparison of selected logging results for probes T47-IF-2 and T47-IF-5.

3.4 Focus Area 1D: Undocumented Disposals

Nine probes were installed in Focus Area 1D to explore for undocumented waste disposals in the SDA (i.e., three in the north and six in the south part of the SDA) as shown in Figures 3-6a and 3-6b. Disposal records contain no additional information concerning possible characteristics of these disposals, if they exist. Focus Area 1D-north probes were installed into regions with elevated soil conductivity. Focus Area 1D-south probes were installed directly adjacent to areas suspected of containing buried metal. Table 3-7 provides the logging completion summary showing depth intervals logged for each Focus Area 1D probe. Table 3-8 provides the radionuclide detection summary for Focus Area 1D.

Table 3-7. Logging completion summary showing depth intervals logged for each Focus Area 1D probe.

| Well_ID | Passive Neutron | | Passive Gamma | | N-gamma | | Moisture | |
|-----------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) |
| ID North | | | | | | | | |
| UD-01 | 2.24 | 9.58 | 2.00 | 10.02 | 2.00 | 8.95 | 0.25 | 10.13 |
| UD-03 | 2.25 | 3.65 | 2.00 | 4.04 | 2.00 | 3.03 | 0.25 | 4.13 |
| UD-03B | 2.25 | 13.84 | 2.00 | 14.22 | 2.00 | 13.22 | 0.25 | 14.33 |
| ID South | | | | | | | | |
| UD-04 | 2.25 | 13.40 | 2.00 | 13.86 | 2.00 | 12.81 | 0.25 | 13.91 |
| UD-05 | 2.25 | 3.62 | 2.00 | 4.03 | 2.00 | 2.83 | 0.25 | 4.13 |
| UD-05B | 2.25 | 4.13 | 2.00 | 4.49 | 2.00 | 3.48 | 0.25 | 4.60 |
| UD-05C | 2.25 | 4.42 | 2.00 | 4.80 | 2.00 | 3.75 | 0.25 | 4.86 |
| UD-05D | 2.25 | 4.56 | 2.00 | 4.92 | 2.00 | 3.92 | 0.25 | 5.00 |
| UD-05E | 2.25 | 9.78 | 2.00 | 10.24 | 2.00 | 9.15 | 0.25 | 10.28 |

Table 3-8. Radionuclide detection summary for Focus Area 1D.^a

| Well_ID | Cs-137 662 keV (pCi/g) | Co-60 1,332 keV (pCi/g) | Pu-239 375 keV (pCi/g) | Am-241 662 keV (pCi/g) | Np-237 312 keV (pCi/g) | U-235 186 keV (pCi/g) | U-238 1,001 keV (pCi/g) | Chlorine 1,151 keV (counts/ second) |
|------------------|------------------------------|----------------------------------|------------------------------|------------------------------|------------------------------|-----------------------------|-------------------------------|--|
| ID North | | | | | | | | |
| UD-01 | ND | ND | ND | ND | ND | ND | ND | 2.3 |
| UD-03 | ND | ND | ND | ND | ND | ND | ND | ND |
| UD-03B | ND | ND | ND | ND | ND | ND | ND | 1.1 |
| ID South | | | | | | | | |
| UD-04 | 42.1 | 157.7 | ND | ND | ND | ND | ND | 1.3 |
| UD-05 | ND | ND | ND | ND | ND | ND | ND | 0.9 |
| UD-05B | 0.5 | ND | ND | ND | ND | ND | ND | 0.0 |
| UD-05C | 0.3 | ND | ND | ND | ND | ND | ND | ND |
| UD-05D | 0.4 | ND | ND | ND | ND | ND | ND | ND |
| UD-05E | 1.9 | ND | ND | ND | ND | ND | ND | 2.3 |
| MAX ^b | 140.5 | 814.2 | 194,171,000 | 30,449,000 | 4,881 | 344.9 | 220,894 | 38 |
| PROBE | 741-04 | P9-FI-05 | P9-20 | 743-08-02 | DU-08 | 743-08 | 743-08 | P9-03 |

a. Concentration estimates obtained from geophysical logging measurements can be significantly affected by heterogeneous subsurface conditions; values presented in this table should be viewed as *apparent* concentration.

b. Maximum observed value of radionuclide or element from all previous SDA logging.

NA = not applicable

ND = not detected

SDA = Subsurface Disposal Area

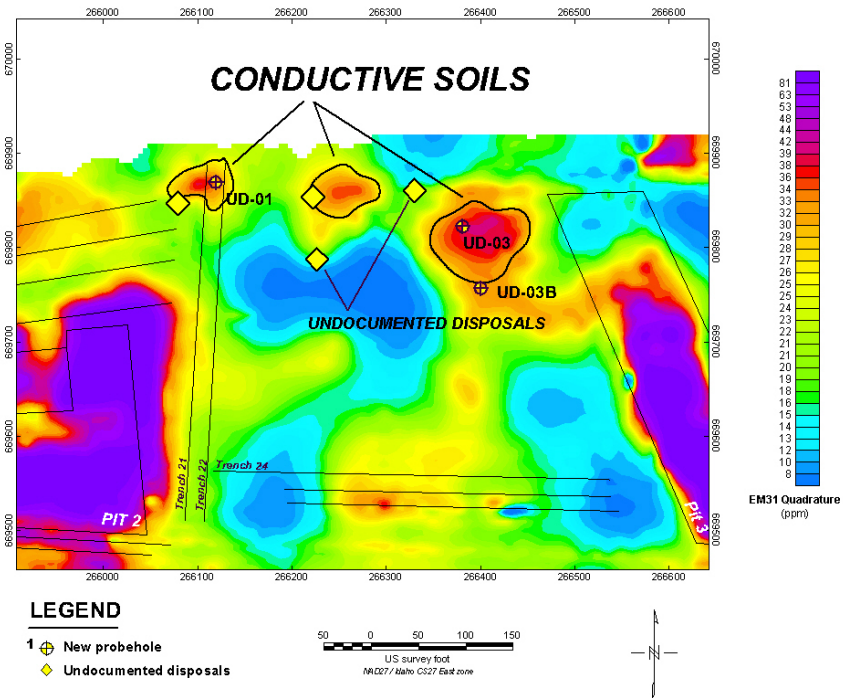


Figure 3-6a. Map showing the areas of conductive soil in Focus Area 1D-north.

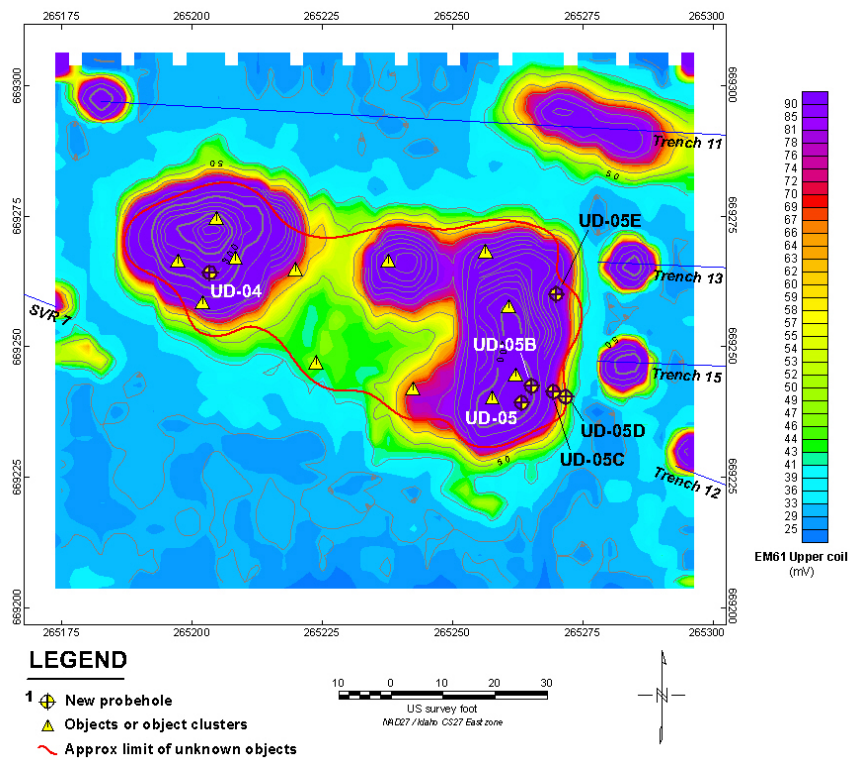


Figure 3-6b. Map showing the location of probes in Focus Area 1D-south.

Table 3-8 shows that no man-made radionuclides were detected within Focus Area 1D-north. Probe UD-03 only penetrated to 4 ft and may not be diagnostic of the subsurface conditions associated with this high soil-conductivity zone. Moisture data suggest a typical soil profile for all probes throughout the logged depths with no apparent presence of significant void space or man-made materials. Probehole UD-01 shows chlorine within the depth interval from 2.0–8.5 ft. Because chlorine has very seldom been detected by logging in clean overburden soils at the SDA, the chlorine indications in Probe UD-01 may be evidence for some type of undocumented disposal. Chlorine was also found at 12.0–12.5 ft in Probe UD-03B. If the elevated soil conductivity and chlorine are related, these data suggest the possible presence of a soluble chlorine compound.

Table 3-8 shows that Cs-137 was detected in five of the six Focus Area 1D-south probes. Low detection levels in the overburden fill soils (less than 5 ft) in probes UD-05B, UD-05C, UD-05D, and UD-05E suggest Cs-137 from nuclear testing fallout. These probes (as well as Probe UD-05) show no other evidence of man-made contaminants except for three low-level chlorine detections in Probe UD-05E and one low-level chlorine detection in Probe UD-05. Probes UD-05 through UD-05D met refusal at depths of 5 ft or less, which suggests the possibility that the probes encountered impenetrable man-made objects.

Cesium-137 and Co-60 were both detected at significant levels in Probe UD-04. The radionuclide zone occurs beneath a clean 5-ft overburden, and has sporadic associated chlorine. No increased neutron flux is observed. Overall, data suggest that Probe UD-04 penetrated a non-RFP radioactive waste disposal.

3.5 Focus Area 2: Naval Reactors Facility Liquid-Waste Disposals

Focus Area 2 targets are Trench 24 liquid-waste disposals associated with a diatomaceous absorbent material. Figure 3-7 shows the location of the targeted shipments and the four new probes, HAL1 through HAL4. Probes HAL1 and HAL2 penetrated 19–21 ft bgs. Probes HAL3 and HAL4, though located only 10–20 ft further east, penetrated only 8–12 ft bgs.

Tables 3-9 and 3-10 present summaries of the logged intervals and the detected contaminants for each of the Focus Area 2 probes. A logging-summary-data chart for each Focus Area 2 probe is included in Appendix B. Note that radionuclide levels are presented in units of activity concentration. These values should be understood as *apparent* concentrations, because the actual concentration is highly dependent on heterogeneity in the vicinity of the probehole.

No americium-neptunium-plutonium, uranium, or significant chlorine is observed in any of the Focus Area 2 probes. Cesium-137 is observed in all the probes, accompanied by Co-60 in probes HAL2 and HAL4. The total gamma activity observed in Probe HAL2 was sufficient to saturate the measurement system throughout an 8.5-ft depth interval such that no useful gamma ray data were obtained. The 8.5-ft depth interval showed elevated neutron flux, suggesting the possible presence of plutonium or americium, although these radionuclides could not be verified because of the high gamma activity.

The cesium-cobalt count rate in Probe HAL4 increases abruptly in the bottom few feet of the probe, suggesting that the radionuclide zone continues below the probe bottom. This may reflect contamination that has migrated into basalt or other hard layer beneath the waste zone, or it may mean that the probe struck impenetrable waste at the refusal depth. In either case, peak radionuclide level for these zones could not be determined.

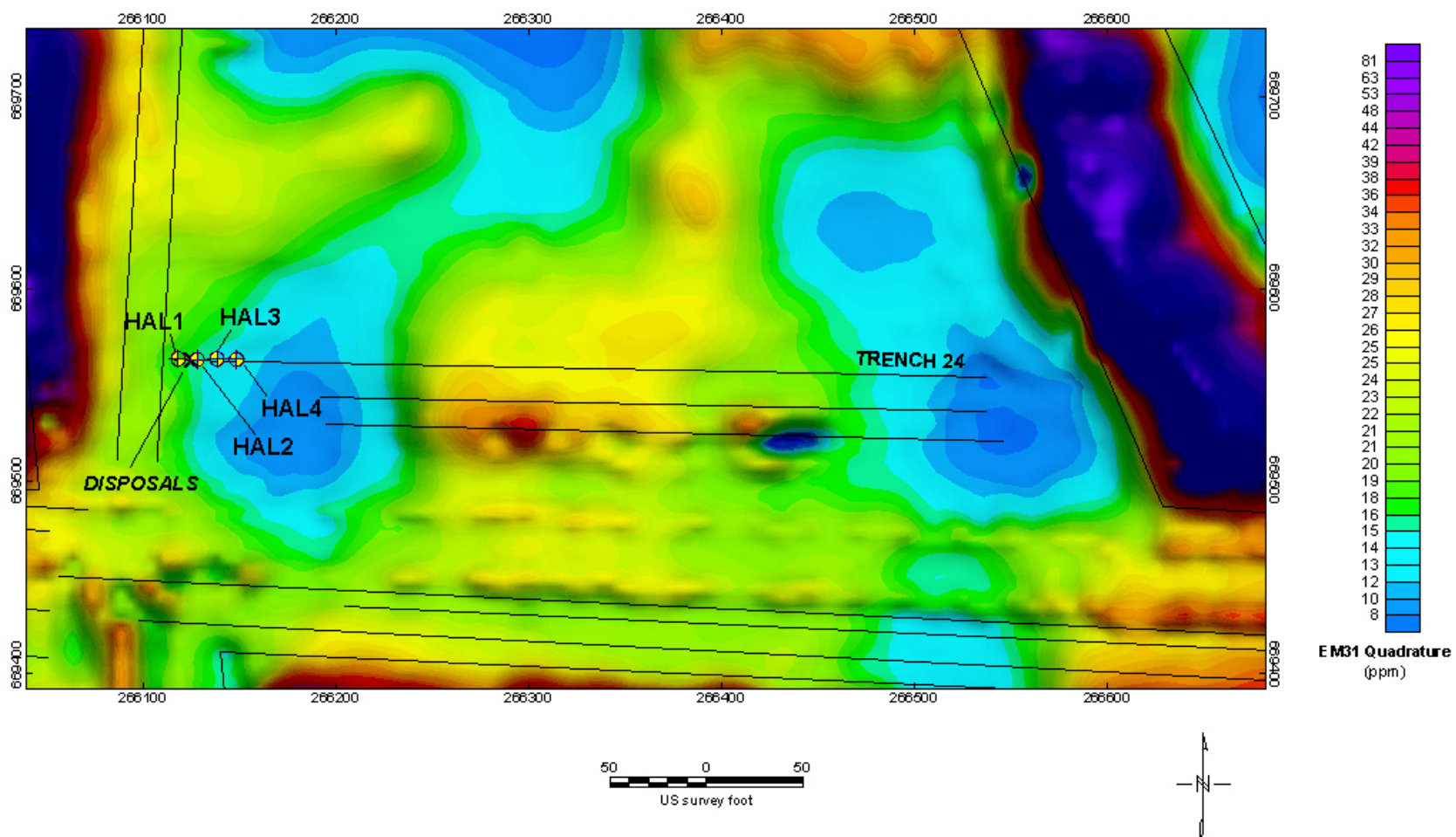


Figure 3-7. Map showing the location of probes HAL1 through HAL4 in Focus Area 2.

Table 3-9. Logging completion summary showing depth intervals logged for each Focus Area 2 probe.

| Well_ID | Passive Neutron | | Passive Gamma | | N-gamma | | Moisture | |
|---------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) |
| HAL1 | 2.25 | 19.21 | 2.00 | 19.65 | 2.00 | 18.58 | 0.25 | 19.68 |
| HAL2 | 2.25 | 21.63 | 2.00 | 22.04 | 2.00 | 21.03 | 0.24 | 22.08 |
| HAL3 | 2.25 | 7.76 | 2.00 | 8.16 | 2.00 | 7.06 | 0.25 | 8.18 |
| HAL4 | 2.25 | 12.04 | 2.00 | 12.48 | 2.00 | 11.42 | 0.25 | 12.52 |

Table 3-10. Radionuclide detection summary for Focus Area 2D.^a

| Well_ID | Cs-137 662 keV (pCi/g) | Co-60 1,332 keV (pCi/g) | Pu-239 375 keV (pCi/g) | Am-241 662 keV (pCi/g) | Np-237 312 keV (pCi/g) | U-235 186 keV (pCi/g) | U-238 1,001 keV (pCi/g) | Chlorine 1,151 keV (counts/ second) |
|------------------|------------------------------|-------------------------------|------------------------------|------------------------------|------------------------------|-----------------------------|----------------------------------|--|
| HAL1 | 0.3 | ND | ND | ND | ND | ND | ND | 0.6 |
| HAL2 | 6,773.5 | 228.0 | ND | ND | ND | ND | ND | 1.0 |
| HAL3 | 1.0 | ND | ND | ND | ND | ND | ND | 0.2 |
| HAL4 | 240.7 | 45.8 | ND | ND | ND | ND | ND | ND |
| MAX ^b | 140.5 | 814.2 | 194,171,000 | 30,449,000 | 4,881 | 344.9 | 220,894 | 38 |
| PROBE | 741-04 | P9-FI-05 | P9-20 | 743-08-02 | DU-08 | 743-08 | 743-08 | P9-03 |

a. Concentration estimates obtained from geophysical logging measurements can be significantly affected by heterogeneous subsurface conditions; values presented in this table should be viewed as *apparent* concentration.

b. Maximum observed value of radionuclide or element from all previous SDA logging.

NA = not applicable

ND = not detected

SDA = Subsurface Disposal Area

Moisture logs for all four probes are very similar, suggesting a common soil and waste environment with depth throughout the probe area. This observation provides no explanation for the large difference in refusal depth for probes HAL3 and HAL4 compared with probes HAL1 and HAL2.

Azimuthal logging was performed at 12.0 and 21.0 ft in probes HAL2 and HAL4, respectively. Azimuthal data are presented in Section 4.5.

3.6 Focus Area 3: Pit 5 Rocky Flats Plant Plutonium and Enriched Uranium Waste

Eight probes were installed in Focus Area 3 within portions of Pit 5 believed to contain RFP waste (see Figure 3-8). Target shipments consisted of 55-gal drums containing RFP Building 776 waste, RFP Building 881 waste, and graphite waste. These shipments could potentially contain highly enriched uranium or Pu-239.

Tables 3-11 and 3-12 present summaries of the logged intervals and detected contaminants for each of the Focus Area 3 probes. A logging data summary chart for each Focus Area 3 probe is included in Appendix B. Note that radionuclide levels are presented in units of activity concentration. These values should be understood as *apparent* concentrations because the actual concentration is highly dependent on heterogeneity in the vicinity of the probehole.

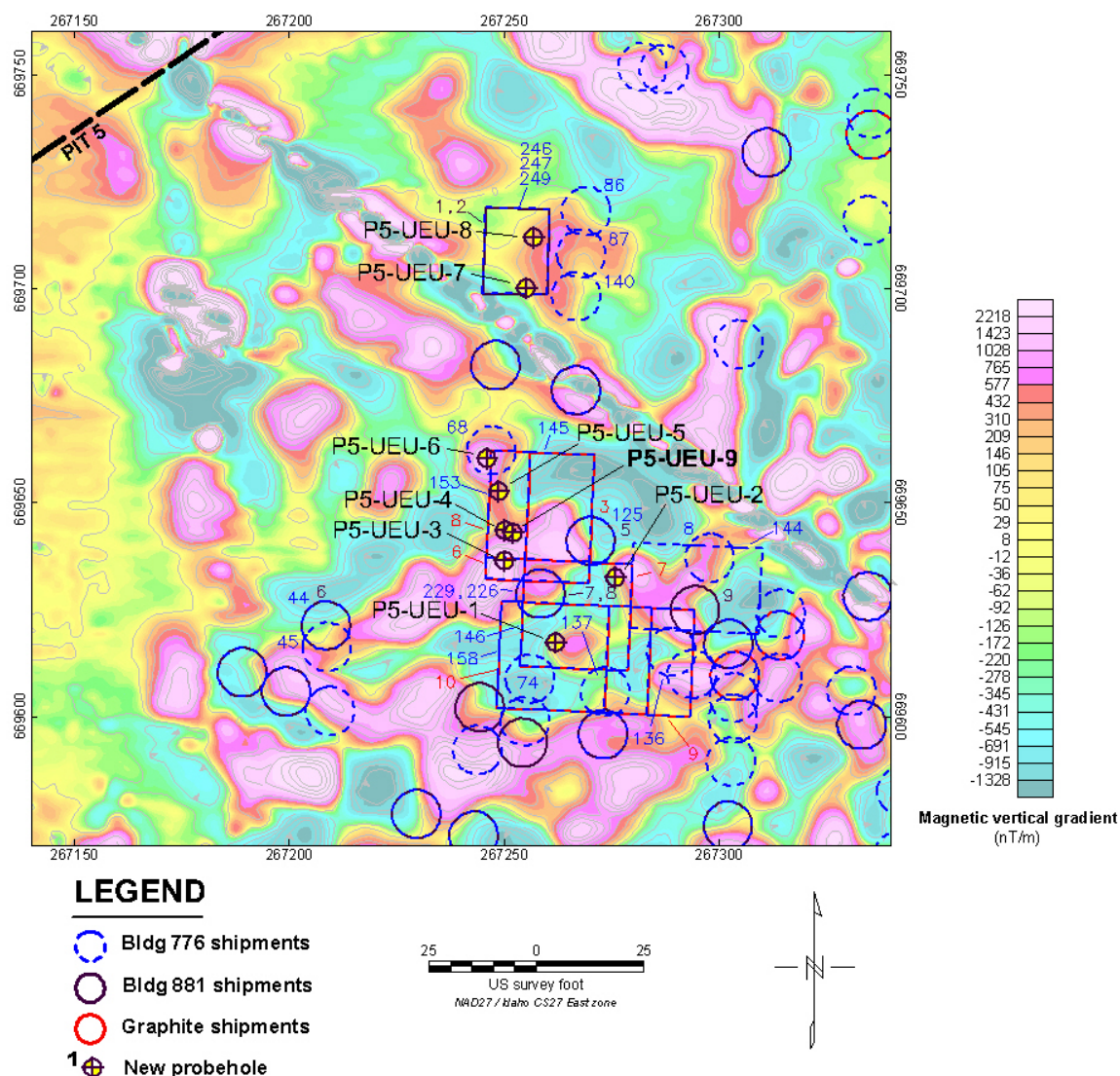


Figure 3-8. Map showing the location of Focus Area 3.

Table 3-11. Logging completion summary showing depth intervals logged for each Focus Area 3 probe.

| Well_ID | Passive Neutron | | Passive Gamma | | N-gamma | | Moisture | |
|----------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) | Minimum (ft bgs) | Maximum (ft bgs) |
| P5-UEU-1 | 4.24 | 17.60 | 4.00 | 18.11 | 4.00 | 17.12 | 0.25 | 18.16 |
| P5-UEU-2 | 4.23 | 17.30 | 4.00 | 17.76 | 4.00 | 16.68 | 0.25 | 17.75 |
| P5-UEU-3 | 4.24 | 15.24 | 4.00 | 15.74 | 4.00 | 14.66 | 0.25 | 15.80 |
| P5-UEU-4 | 4.25 | 16.80 | 4.00 | 17.27 | 4.00 | 16.18 | 0.25 | 17.29 |
| P5-UEU-5 | 4.25 | 15.26 | 4.00 | 15.70 | 4.00 | 14.66 | 0.25 | 15.79 |
| P5-UEU-6 | 4.24 | 15.06 | 4.00 | 15.51 | 3.98 | 14.46 | 0.25 | 15.57 |
| P5-UEU-7 | 4.25 | 16.19 | 4.00 | 16.64 | 4.00 | 15.54 | 0.25 | 16.71 |
| P5-UEU-8 | 4.25 | 11.26 | 4.00 | 11.72 | 4.00 | 10.64 | 0.25 | 11.74 |
| P5-UEU-9 | 4.25 | 16.78 | 4.00 | 17.13 | 4.00 | 16.10 | 4.25 | 17.27 |

Table 3-12. Radionuclide detection summary for Focus Area 3.^a

| WELL ID | Cs-137 662 keV (pCi/g) | Co-60 1,332 keV (pCi/g) | Pu-239 375 keV (pCi/g) | Am-241 662 keV (pCi/g) | Np-237 312 keV (pCi/g) | U-235 186 keV (pCi/g) | U-238 1,001 keV (pCi/g) | Chlorine 1,151 keV (counts/ second) |
|------------------|------------------------------|-------------------------------|------------------------------|------------------------------|------------------------------|-----------------------------|-------------------------------|--|
| P5-UEU-1 | ND | 0.3 | 3,074,661.0 | 1,370,885.8 | 12.2 | ND | ND | 38.7 |
| P5-UEU-2 | ND | ND | 1,272,732.6 | 4,350,311.1 | 52.5 | ND | 363.8 | 4.9 |
| P5-UEU-3 | ND | ND | 5,330,961.1 | 1,668,578.2 | 21.4 | 10.5 | 940.6 | 20.4 |
| P5-UEU-4 | ND | ND | 31,924,850.6 | 8,106,524.5 | 96.5 | 26.4 | 2,102.5 | 34.6 |
| P5-UEU-5 | ND | ND | 3,214,037.3 | 6,104,438.0 | 87.7 | 109.3 | 32,920.6 | 1.9 |
| P5-UEU-6 | ND | ND | 2,399,686.7 | 4,285,269.1 | 62.3 | ND | 63.4 | 5.2 |
| P5-UEU-7 | ND | ND | 11,800,803.1 | 2,759,951.1 | 26.4 | 2.8 | ND | 24.2 |
| P5-UEU-8 | ND | ND | 219,000.5 | 387,750.5 | ND | ND | 29.1 | 6.2 |
| P5-UEU-9 | ND | ND | 1,491,067.5 | 2,098,481.9 | 32.5 | ND | 1,274.2 | 10.1 |
| MAX ^a | 140.5 | 814.2 | 194,171,000 | 30,449,000 | 4,881 | 344.9 | 220,894 | 38 |
| PROBE | 741-04 | P9-FI-05 | P9-20 | 743-08-02 | DU-08 | 743-08 | 743-08 | P9-03 |

a. Concentration estimates obtained from geophysical logging measurements can be significantly affected by heterogeneous subsurface conditions; values presented in this table should be viewed as *apparent* concentration.

b. Maximum observed value of radionuclide or element from previous SDA logging.

NA = not applicable

ND = not detected

SDA = Subsurface Disposal Area

All nine Study Area 3 probes encountered high levels of americium, neptunium, and plutonium. Although higher levels of americium, neptunium, and plutonium have been observed in some other SDA probes, the Focus Area 3 americium-neptunium-plutonium radionuclide zone is unique because the very high radiation levels are sustained over a thick interval, with peaks at about 8–9 and 13–15 ft bgs. Very high chlorine peaks also are observed. The americium-neptunium-plutonium, uranium, and chlorine contamination zones are closely correlated and give the general impression of two vertically stacked waste zones. The similarity between logging results for these probes is somewhat surprising because the probes are scattered along nearly 100 ft of Pit 5, and are associated with several distinctly separate geophysical anomalies.

Elevated thorium is observed to coincide with some, but not all, americium-neptunium-plutonium peaks. Elevated thorium has been observed in logging data elsewhere in the SDA, but the source and significance of this phenomenon is not known (see Appendix C). The only plausible thorium series decay disequilibrium that could account for the observed discrepancy is an excess of Th-228 relative to Th-232. Separation of Th-228 from Th-232 in the subsurface by geochemical processes is too improbable to consider, so mechanisms other than decay of Th-232 that could produce thorium-series nuclides below Ac-228 were investigated. An example is alpha decay of U-232 to Th-228. None of the mechanisms produce detectable gamma rays, so the passive gamma ray spectra do not contain information that can confirm or rule out such processes.

All probes, except Probe P5-UEU-1, contain U-238, U-235, or both uranium isotopes. Table 3-13 gives the U-235:U-238 activity ratios and mass ratios at each point where both U-235 and U-238 were detected. These ratios have not been corrected for differential gamma ray attenuation, but are suggestive of depleted or natural uranium. The single exception is near the bottom of Probe P5-UEU-7, where U-235 was detected without U-238. The U-235 in this probe was just above the minimum detection level. Note that the “natural” uranium observed in Probe P5-UEU-5 (see KUT chart for Probe P5-UEU-5 in Appendix B) is also elevated, suggesting that, at least for Probe P5-UEU-5, uranium could occur in the form of uranium ore or other uranium material from early in the fuel-production cycle.

Table 3-13. Summary of uranium detection in Focus Area 3.^a

| Well ID | Depth (ft) | U-235 ^b 0186-keV (pCi/g) | U-238 1,001-keV (pCi/g) | Activity Ratio ^b U-235:U-238 | Mass Ratio ^b U-235:U-238 |
|----------|------------|---|-------------------------------|--|--|
| P5-UEU-3 | 13.0 | 10.5 | 883.4 | 0.019 | 0.0018 |
| P5-UEU-3 | 13.5 | 7.6 | 940.6 | 0.008 | 0.0013 |
| P5-UEU-4 | 13.0 | 15.7 | 1,436.3 | 0.011 | 0.0017 |
| P5-UEU-4 | 14.0 | 25.3 | 1,933.1 | 0.013 | 0.0020 |
| P5-UEU-4 | 13.5 | 26.4 | 2,102.5 | 0.013 | 0.0020 |
| P5-UEU-5 | 10.5 | 14.5 | 2,236.6 | 0.006 | 0.0010 |
| P5-UEU-5 | 11.0 | 30.4 | 2,354.0 | 0.013 | 0.0020 |
| P5-UEU-5 | 10.0 | 33.6 | 6,530.2 | 0.005 | 0.0008 |
| P5-UEU-5 | 9.5 | 63.0 | 13,968.6 | 0.005 | 0.0007 |
| P5-UEU-5 | 9.0 | 109.3 | 30,933.9 | 0.004 | 0.0005 |
| P5-UEU-5 | 8.5 | 75.9 | 32,920.6 | 0.002 | 0.0004 |
| P5-UEU-7 | 14.5 | 2.8 | ND | No value | No value |

a. Concentration estimates obtained from geophysical logging measurements can be significantly affected by heterogeneous subsurface conditions; values presented in this table should be viewed as *apparent* concentration.

b. U-235 apparent concentrations not corrected for potential Ra-226 interference.

c. The following are derived from constants obtained from GE (1989): (1) typical activity ratios: <0.04507 (depleted), 0.04507 (natural), >0.04507 (enriched); (2) typical mass ratios: <0.00696 (depleted), 0.00696 (natural), >0.00696 (enriched).

ND = nondetect

Figure 3-9 shows a comparison between probeholes P5-UEU-4 and P5-UEU-9. Logging data from Probeghole P5-UEU-4 suggest two distinct waste streams: an upper waste stream from 8.5–11 ft characterized by high plutonium-amerium-neptunium and chlorine and a lower waste stream from 11–14 ft dominated by amerium-neptunium with only minor plutonium and chlorine. The interval from 9–10.5 ft in Probeghole P5-UEU-9 exhibits plutonium-amerium-neptunium-chlorine characteristics similar to the upper waste stream in Probeghole P5-UEU-4, but at lower levels. This waste stream could be continuous between these probes. The lower waste stream in Probeghole P5-UEU-4 has no clear counterpart in Probeghole P5-UEU-9, and does not appear to be continuous between the two probes. These two probes are located only 2.0 ft apart. The ambiguous correlation between logging data over this short distance provides an excellent illustration of the apparent heterogeneity of the waste zone.

Azimuthal logging was conducted in probegholes P5-UEU-1 (10 depths), P5-UEU-4 (two depths), P5-UEU-5 (three depths) and P5-UEU-7 (five depths). Azimuthal data are presented in Section 4.5.

3.7 Focus Area 4: Pit 10 Plutonium Waste (741-08 Probe Cluster)

Four new probes (i.e., 741-10, 741-11, 741-08C, and 741-08D) were installed in Focus Area 4 to assist in the interpretation of results from previously installed Type A probes (i.e., 741-08, 741-08A, and 741-08B) and Type B lysimeters (i.e., 741-8-L1 and 741-8-L2) in Pit 10 (see Figure 3-10). The previously installed probes indicated at least two separate sources of plutonium, but the location and extent of these sources could not be determined. The new probes provided additional information about the distribution of plutonium sources.

Tables 3-14 and 3-15 present summaries of the logged intervals and the detected radionuclides for each of the Focus Area 4 probes. A logging data summary chart for each Focus Area 4 probe is included in Appendix B. Note that radionuclide levels are presented in units of activity concentration. These values should be understood as *apparent* concentrations, because the actual concentration is highly dependent on heterogeneity in the vicinity of the probeghole.

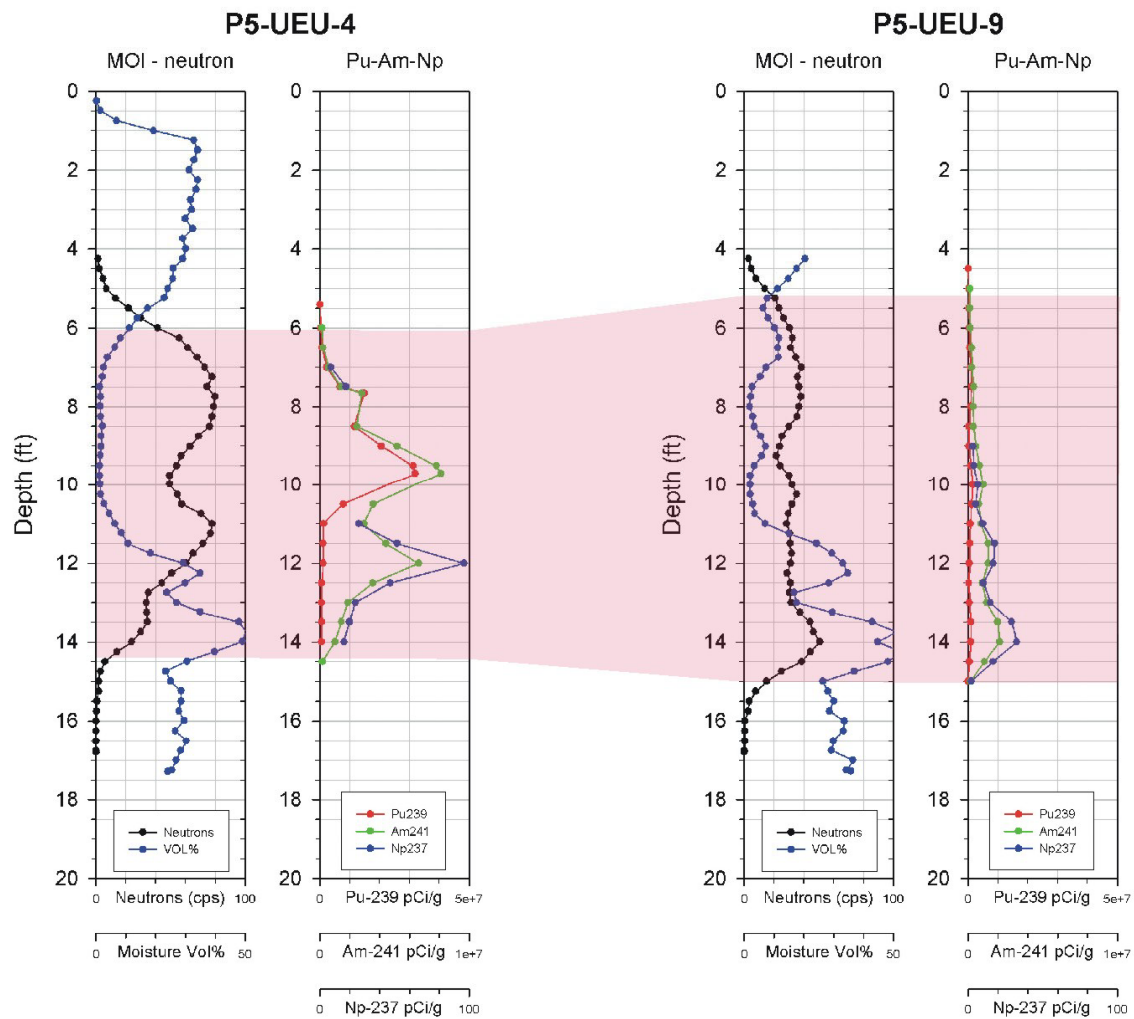


Figure 3-9. Comparison of selected logging results for probes P5-UEU-4 and P5-UEU-9.